

**INTERIM DESIGN AND REVIEW
GUIDELINES
FOR
WOOD FIRED COMBUSTORS**

APPROVALS BRANCH

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PREFACE

Proponents of wood fired combustors are required to submit applications for certificates of approval under Section 8, and in certain cases Section 27 of the Environmental Protection Act.

In addition, some large wood fired combustors may be designated under the Environmental Assessment Act.

It is noted that "fuel burning equipment used solely for the purpose of comfort heating in a dwelling used for the housing of not more than three families", is exempt from the requirement of an approval under Section 8 of the Act pursuant to Section 3.(3) of Regulation 308 under the Environmental Protection Act.

The general approval requirements are outlined in the table presented in Appendix I.

GENERAL

This basic design and review guideline is intended to assist the Approvals Branch in their review of Section 8 applications for wood fired combustion facilities until such time that a final guideline and a formal policy are in place. The guideline is expected to ensure a consistent review process and a reasonable confidence in protection of the environment.

Appendix II outlines the intent of this guideline in the form of a quick reference table.

A formal policy may be developed based on this interim guideline, after stack test results as well as adequate operating experience are available for the approved facilities.

TEMPERATURE AND RETENTION TIME

All wood fired combustors shall be designed such that they can be operated on a continuous basis at a minimum temperature of 1000°C with a minimum retention time of 1 second for the combustion gases.

The above requirement is consistent with Policy 01-01 and is expected to reduce emissions of toxic organics, such as benzene, dioxins and furans, polycyclic organic matter (POM) including PAHs etc., which have been found to be emitted from combustion of virgin as well as treated wood.

An auxiliary gas or oil fired burner is recommended for the purpose of achieving the required combustion temperature prior to feeding any wood into the unit. The auxiliary burner is required in cases when the combustor may be operated intermittently or may otherwise be subject to start-ups more than five times a week.

The above requirements may necessitate inclusion of a secondary chamber in the combustor design. It is expected that the secondary chamber will also enhance mixing of oxygen and combustion gases thus improving the combustion process.

OXYGEN AVAILABILITY

All wood fired combustors shall be designed to provide and shall operate at not less than 6 % residual oxygen in the flue gas. A preferred range is 6 to 8 %.

AIR POLLUTION CONTROL EQUIPMENT

• Clean Wood

Facilities, which are to be approved for combustion of virgin wood, such as sawdust, woodchips, bark etc., shall, with or without air pollution control equipment, be capable of achieving a particulate concentration of not more than 90 mg/Rm³ (milligrams per dry cubic metre normalized to 11 % O₂ at a reference (R) temperature of 25°C and a reference pressure of 101.3 kPa) in the undiluted flue gas.

This particulate outlet concentration limit is considered to be a target for smaller units (wood firing rate less than 10 tonnes per day).

The target particulate outlet concentration for large wood fired combustors (firing rate more than 200 tonnes per day) shall be 50 mg/Rm³ in the above reference conditions.

• Treated Wood

Facilities, which are to be approved for combustion of treated wood, such as salt laden wood, particleboard, wood treated with preservatives or stain prevention agents etc., will require equipment adequate to reduce the emissions of the identified contaminants. At the very least, these facilities shall be equipped with air pollution control equipment capable of achieving a particulate concentration of not more than 20 mg/Rm³ (milligrams per dry cubic metre normalized to 11 % O₂ at a reference (R) temperature of 25°C and a reference pressure of 101.3 kPa) in the undiluted flue gas.

This requirement is consistent with the Particulate Outlet Concentration stipulated in Policy 01-03, and is intended to reduce emissions of toxic metals as well as polychlorinated dibenzodioxins and dibenzofurans, which may be formed during combustion and may be attached to particulate matter.

This particulate outlet concentration limit is considered to be a target for smaller units (wood firing rate less than 10 tonnes per day).

It is noted that the temperature of the flue gas shall be lowered as much as practical (preferred range 110 - 140°C) prior to the final particulate collection device in order to avoid conditions that favour formation of dioxins and furans and also to condense metal fumes.

Appendix III provides information on commonly available wood treatment chemicals.

No foreign materials, solvents or other contaminants, shall be allowed in wood scraps destined to be burned in wood fired combustors.

COMPLIANCE WITH POINT OF IMPINGEMENT CONCENTRATION STANDARDS

The reviewers shall verify compliance with all relevant point of impingement concentration standards and guidelines by carrying out dispersion calculations in accordance with Regulation 308 under the Environmental Protection Act.

It is noted that Regulation 308 is currently under review for upgrade and update. These Design and Review Guidelines will adhere to the new requirements of the Clean Air Program in accordance with the implementation schedule included in the new or revised regulations.

PERFORMANCE TESTING

All combustors, which burn over 100 tonnes per day of wood, shall undergo Performance Testing in accordance with an ASME (American Society of Mechanical Engineers) Power Test Code (short method acceptable) in order to obtain information on:

- (i) the adaptability of the equipment;
- (ii) best methods of operation;
- (iii) capacity and efficiency; and
- (iv) a verification of Manufacturer's guarantees.

A typical Test Code is provided for reference in Appendix IV.

Proponents of smaller units should also be encouraged to carry out a Performance Test or a modified acceptance test.

SOURCE TESTING

Source testing shall be required for all wood fired combustors. The following outlines *minimum requirements* as well as *preferred additional requirements*. Comprehensive flue gas sampling and analysis shall be required, if the proponent receives funding assistance from government sources.

The samples shall be analyzed as follows:

- Suspended particulate matter as a minimum requirement for all wood fired combustors. The source testing report shall include records of CO monitor readings during flue gas sampling.

- Polycyclic Organic Matter (POM), as listed in Appendix V, required for combustors burning more than 2 tonnes per day of wood. Optional for smaller combustors.
- Total polychlorinated dioxins and furans required for combustors burning:
 - (i) more than 2 tonnes per day of treated wood, or
 - (ii) more than 10 tonnes per day of any type of wood.

Optional for other combustors. Individual congeners may be required later if there appears to be concern regarding dioxins and furans.

- Selected metals required for all combustors burning more than 2 tonnes per day of treated wood that may contain toxic metals.

Additional analyses may be required on a case by case basis depending on the suspected contaminants.

The above testing requirements are considered necessary for the purpose of developing a database for emissions from wood fired combustors. Information available from earlier stack tests on substantially identical units under substantially identical operating conditions may be used at the discretion of the review engineer, but it is strongly recommended that some source testing be required for all facilities until a good database is available.

It is recognized that POI concentration guidelines are not available for all POMs, however, the Hazardous Contaminants Coordination Branch is currently working on a scientific criteria document for all PAHs. Therefore, POM emission information is valuable in order to gain a full understanding of the potential environmental hazards that may be associated with wood firing. It is noted that the facilities which may escape the testing requirements at this time, will most likely be caught later upon implementation of the Clean Air Program.

CONTINUOUS PROCESS AND EMISSION MONITORING

- Temperature

All wood fired combustors shall be equipped with temperature sensors at the point representing one second retention time. Continuous temperature recorders shall be installed for the purpose of providing a verification of the combustion temperature. In lieu of a continuous temperature recorder, the proponent may undertake to keep hourly records of the temperature readings and provide the records for inspection by MOE staff.

- Opacity

A continuous double pass opacity meter shall be installed downstream of air pollution control equipment prior to any dilution of the flue gases for all combustors firing more than 2 tonnes per day of wood.

The monitor shall be equipped with a recorder and an alarm set at 20 % opacity.

Periodic testing (once a month as a minimum) with a portable opacity meter may be required for smaller units.

In lieu of an opacity meter, combustors controlled by a baghouse may be equipped with pressure sensing devices to monitor changes in the pressure drop across each baghouse compartment in order to detect bag failures.

- Carbon Monoxide

A continuous CO monitor shall be installed in the flue for all combustors firing more than 2 tonnes per day of woodwaste. The monitor shall be equipped with a recorder.

A target CO level shall be 100 ppm, however, this number may be adjusted after Performance Testing.

Periodic testing with a portable CO monitor may be required for smaller units.

- Oxygen

A continuous oxygen monitor shall be installed in the flue for all combustors firing more than 10 tonnes per day of wood.

The oxygen monitor shall be equipped with a recorder.

Periodic testing with a portable oxygen monitor may be required for smaller units.

BOTTOM RESIDUE AND FLYASH HANDLING (if no Part V application is required)

If the wood contains, or is suspected of containing, contaminants listed in Schedule 4 of Regulation 309 under the Environmental Protection Act, the residue from the fire box and the particulate matter collected in the air pollution control equipment shall be tested separately, using triplicate samples, according to the leachate extraction procedure described in Regulation 309.

All materials, which are required to be tested, shall be stored separately on site until test results are available. The owner/operator of the wood fired combustor shall then register the wastes, if required, pursuant to Section 15. (1) and (15)(b) of Regulation 309, and cause the disposal of the wastes at appropriately approved disposal sites.

MAINTENANCE

The combustor, the air pollution control as well as continuous monitoring equipment shall be maintained in accordance with the manufacturers' recommendations in order to ensure that performance of the equipment does not deteriorate over time.

The Proponent shall implement Best Management Practices (BMP) to ensure appropriate maintenance and operation of the wood fired combustor. As part of the BMP, the Proponent shall provide adequate operator training, including periodic retraining and upgrade.

CONDITIONS ON APPROVAL

The requirements of this interim guideline shall be enforced by setting conditions on certificates of approval.

APPENDIX I

GENERAL APPROVAL REQUIREMENTS

APPROVAL OF WOOD FIRED COMBUSTORS

WOOD FIRING RATE				
TONNES PER DAY AS FIRED	<100		100-600	>600
STORAGE CAPACITY	<500 m ³ AND <6 MONTHS	>500 m ³ OR >6 MONTHS	ANY	ANY
WITH HEAT RECOVERY	S.9	S.9 + PART V	S.9 + PART V	S.9 + PART V + EA
WITHOUT HEAT RECOVERY	S.9	S.9 + PART V	S.9 + PART V + EA	S.9 + PART V + EA

source: Section 28.1 (2) of Reg 347

Note:

- (1) Woodwaste combustor site for residential heating is exempt from Part V if not more than 50 m³ of wastewood is stored at the wastewood combustor site. (Section 28.1 (1) of Reg 347)
- (2) Woodwaste combustor site is exempt from PART V if the wood waste combustor site was first put into operation before September 26, 1992 and if no PART V was required for its use or operation prior to that date. (Section 28.1 (3) of Reg 347)
- (3) Woodwaste combustor site ceases to be exempt from PART V under (2) if its use or operation changes substantially. (Section 28.1 (4) of Reg 347)
- (4) Woodwaste combustor site ceases to be exempt from PART V under (2) if it is in operation for fewer than 30 days during the period September 26, 1992 to September 26, 1993. (Section 28.1 (5) of Reg 347)

APPENDIX II

QUICK REFERENCE TABLE

EXPLANATORY NOTES FOR APPENDIX I

1. "EA" means an environmental assessment in accordance with the Environmental Assessment Act.
2. "m³" means cubic metres.
3. "PART V" means a certificate of approval under Section 27, Part V of the Environmental Protection Act, known as the "waste site approval"
4. "S.9" means a certificate of approval under Section 9 of the Environmental Protection Act, R.S.O. 1990, known as the "air approval".
5. "Reg 347" means Regulation 347, R.R.O. 1990, enacted under the Environmental Protection Act, R.S.O. 1990.

WOOD TREATMENT CHEMICALS

Predominant wood treatment chemicals in Canada

Wood Preservatives

- CCA (chromated copper arsenate) - major CCA-treated products include fence posts, lumber for patios and landscaping, foundation lumber and plywood.
- ACA (ammoniacal copper arsenate) - major ACA-treated products include utility poles and landscaping timbers.
- PCP (pentachlorophenol) - major PCP-treated products include railway ties and utility poles.
- Creosote - major uses include treatment of railway ties, utility poles and marine pilings.

Antisapstain products

- Azaconazole
- Copper-8-quinolinolate
- Didecyldimethyl ammonium chloride (DDCA)
- 3-iodo-2-propynyl butyl carbamate (IPBC)
- Borax
- 2-(thiocyanomethylthio) benzothiazole (TCMTB)
- 2,3,4,6-sodium tetrachlorophenate
- sodium pentachlorophenate

products such as railroad ties, bridge and mine timbers, and utility poles are usually in direct contact with moist soil or in locations where moisture collects and cannot readily evaporate. When there is no practical means of limiting moisture content, oxygen levels or temperature, the option for the protection of such wood products is limited to the application of chemicals which act as agents to limit fungal growth by "poisoning" the wood food source. Simultaneously, the treatment can limit the other wood-destroying organisms such as insects and wood-borers.

1.3 Wood Preservation Chemicals

Historically, the preservation of wood by chemical means can be traced back over 4000 years, to the time when the Egyptians apparently used bitumen to treat wooden dowel-pins in the stonework of temples (4). At the time of the Roman Empire, tar, linseed oil, oil of cedar, and mixtures of garlic and vinegar were used for the preservation of wooden statues. Alexander the Great of Persia is reported to have ordered piles and other timber for bridge building to be covered with olive oil as a precaution against decay (5). Investigations to define alternative wood preservation agents were reported in the late 1600s with escalating efforts during the 1800s. A review of the many chemicals and chemical formulations used historically and currently can be found in the above references and in texts such as those written by Hunt and Garratt (6) and Wilkensen (7).

The choice of wood preservative depends upon the character of the wood to be treated, the required service, and the properties of the chemical or formulation. Wood preservation formulations must:

- be toxic to attacking organisms;
- be able to penetrate wood;
- be chemically stable;
- be safe to handle;
- be economical to use;
- not weaken the structural strength of the wood; and
- not cause significant dimensional changes within the wood.

Other factors which determine the selection of wood preservation chemicals or formulations include: fire resistance; colour or odour; paintability; corrosiveness; electrical conductivity; and, leachability from wood.

In Canada the predominant wood preservative chemicals or formulations in use are:

- CCA (chromated copper arsenate). Major CCA-treated products include: fence posts, lumber for patios and landscaping, and foundation lumber and plywood.
- ACA (ammoniacal copper arsenate). Major ACA-treated products include: utility poles and landscaping timbers.
- PCP (pentachlorophenol). Major PCP-treated products include: railway ties and utility poles.
- Creosote. Major uses include treatment of railroad ties, utility poles, and marine pilings.

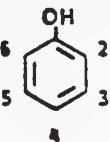
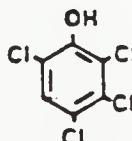
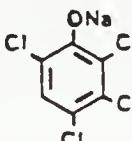
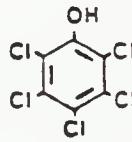
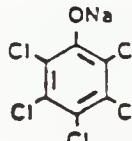
Although other wood preservatives have been used in the past in Canada, the four chemicals or formulations noted above are the only preservatives in use in Canada since 1982. The development of alternative chemicals for wood preservation is the subject of ongoing research. The actual use of alternative chemicals will depend on industry and safety evaluations, and on approval under the Federal Pest Control Products Act administered by Agriculture Canada.

1.4 The Value of Wood Preservation

Controlled studies have shown that wood preservation enhances the life-time utility of wood by factors of 5 to 15, depending on the wood species, use and efficacy of treatment. It has been estimated that, if in the U.S.A. "untreated wood were used for the applications now employing preservative-treated wood, the added annual cost to the transportation, utility, and construction industries would be over \$15 billion dollars. Energy savings, depending on the substitute materials envisioned, are from 19 to 32 million barrels of petroleum per year" (8).

It has also been estimated that if wood were not treated with preservation chemicals, timber requirements would increase by three- to six-fold. Such requirements would have exhausted many timber resources required for railway, utility, construction and marine industries (6). Wood preservation also enables the use of smaller and faster growing trees such as lodgepole pine. Prior to the wide-spread use of wood preservation, timbers used in structures such as railway bridges were required to be over-sized in order to accommodate a degree of decay.

TABLE 1. COMMERCIAL USES OF TETRA- AND PENTACHLOROPHENOL COMPOUNDS

CHLOROPHENOL COMPOUND	CHEMICAL STRUCTURE	COMMON COMMERCIAL USES*
TERMINOLOGY FOR SPECIFYING CHLORINE POSITIONS ON THE PHENOL MOLECULE		THE NUMERICAL PREFIX IN THE COMPOUND NAME INDICATES THE POSITION OF THE CHLORINE ATOM(S)
2,3,4,6-TETRACHLOROPHENOL		PESTICIDE
2,3,4,6-SODIUM TETRA-CHLOROPHENATE (the water soluble sodium salt of 2,3,4,6-tetrachlorophenol)		SAPSTAIN CONTROL AGENT (the primary active ingredient of Canadian formulations commonly used in British Columbia)
PENTACHLOROPHENOL		WOOD PRESERVATIVE (termiticide, fungicide) CONTROL AGENT FOR MOULD ON INERT SURFACES (construction industry) CONTROL AGENT FOR MOULD ON LEATHER SHOE UPPERS FUNGICIDE IN PROTEIN-BASED LATEX PAINTS
SODIUM PENTACHLOROPHENATE (the water soluble sodium salt of pentachlorophenol)		SAPSTAIN CONTROL AGENT (the secondary active ingredient in Canadian formulations; the primary active ingredient in U.S. formulations) ANTIFUNGAL, ANTIBACTERIAL AGENT: <ul style="list-style-type: none"> - In adhesives (starch, vegetable and animal protein-based) - on Inert surfaces (construction materials) - on leather, hides and in tanning solutions - In paint (protein-based) - In drilling muds - photographic solutions - paper pulp and fibre board - textiles (yarns and cloth) - Industrial recirculating cooling waters

*BASED ON INFORMATION IN REFERENCES 3 AND 4

APPENDIX III

WOOD TREATMENT CHEMICALS

APPROVAL GUIDELINE FOR

WOOD FIRED COMBUSTORS

FIRING RATE IN TONNES PER DAY	TEMP., RET. TIME AND OXYGEN	CONTIN. MONITOR. REQ'T	PARTIC. STACK CONC. LIMIT (mg/Rm ³)	MINIMUM STACK TESTING REQ'T	ADDIT. STACK TESTING REQ'T
< 2	1000°C 1s 6 % O ₂	TEMP.	TARGET 20 (TREATED WOOD) TARGET 90 (CLEAN WOOD)	PARTIC. CO ⁻	POM ¹ DIOX/FU ² METALS ⁴
2-10		TEMP. OPACITY CO		PARTIC. CO ⁻ POM ¹ DIOX/FU ^{2,3} METALS ⁴	DIOX/FU ²
> 10		TEMP. OPACITY CO OXYGEN	20 (TREATED WOOD) 90 / 50 ⁵ (CLEAN WOOD)	PARTIC.. CO ⁻ POM ¹ DIOX/FU ² METALS ⁴	

— CONTINUOUS MONITOR READING DURING STACK TEST
POM LIST IN APPENDIX V

¹ TOTAL DIOXINS (DIOX) AND FURANS (FU); INDIVIDUAL CONGENERS MAY BE REQUIRED LATER
² IF CHLORINE PRESENT IN WOOD FEED

³ IF METALS KNOWN OR SUSPECTED TO BE PRESENT IN THE WOOD FEED

⁴ TARGET OF 50 MG/M³ SHOULD BE USED FOR LARGE COMBUSTORS > 200 T/D

TABLE 3.3 PHYSICAL AND CHEMICAL PROPERTIES OF AMMONIUM HYDROXIDE

Identification	
Common Synonyms: Aqua ammonia, Ammonium hydrate, Ammonium solution, Ammonia water, Ammonia liquor	Manufacturers: • Canadian Industries Ltd., Courtright, Ontario • Canadian Fertilizers Ltd., Medicine Hat, Alberta • Cominco Ltd., Carseland, Alberta • Cyanamid Canada Ltd., Niagara Falls, Ontario • Simplot Chemical Ltd., Brandon, Manitoba • Western Co-op Fertilizers Ltd., Calgary, Alberta
Transportation and Storage Information	
Shipping State: Liquid	Storage Temperature: Ambient
Concentrations	Hoses: PVC, rubber, polyethylene steel or stainless steel fittings only
Grade A: 29.4% USP, 27 to 29% CP, 28% C, 15%	Venting: Provide scrubbing of vents to meet air discharge regulatory requirements
Classification: Corrosive liquid	Containers/Materials: Plastic bottles, drums, tank trucks tank cars (steel or steel polylined). Use all iron or SS pumps (no copper alloys, brass or bronze).
Physical and Chemical Properties	
Physical State: Liquid (20°C, 1 Atm)	Floatability: Floats and mixes with water
Vapour Pressure:	Flash Point: Flammable as ammonia
10% ammonia 31 mm Hg 88 mm Hg 238 mm Hg	Explosive Limits: Mixtures of ammonia in air (16-25% by volume) in an enclosed space can ignite or explode if sparked or exposed to temperatures exceeding 630°C (1200°F).
20% ammonia 310 mm Hg	
30% ammonia 786 mm Hg	
Solubility: Freely soluble (water)	
Hazard Data	
Fire	Extinguishing Data: Liquid is non-flammable. Most extinguishing agents can be used on fires involving ammonium hydroxide. Fire Behaviour: Liquid not flammable. Mixtures of ammonia and air can ignite or explode (see above). When exposed to fire, the liquid solution releases ammonia gas and aromatic fumes. Ignition Temperature: Not flammable as liquid; ammonia is flammable at 649°C. Burning Rate: Not flammable
	With Water: No reaction; soluble With Common Materials: Copper, tin, zinc alloys are readily corroded. Reacts with acrolein, acrylic acid, chlorosulphonic acid, dimethyl sulphate, halogens, hydrochloric acid, hydrofluoric acid, nitric acid, sulphuric acid, oleum, propylene oxide and silver nitrate. Avoid contact with aluminum or zinc. Reactivity: Stable

TABLE 3.4 PHYSICAL AND CHEMICAL PROPERTIES OF ARSENIC ACID (75% Solution)

Identification		Transportation and Storage Information		Physical and Chemical Properties		Hazard Data	
Common Synonyms: Orthoarsenic acid		Manufacturers: ASARCO Inc., N.Y., N.Y. Supplied by J.H. Baxter and Co. (San Mateo, CA)		Labels: Check with the Department of Transport		With Water: No reaction; soluble	
Concentration: 75% by weight		Venting: Liquid solution requires venting		With Common Materials: Contact with reducing agents will liberate arsenic (AsH_3), a colorless, highly toxic gas. Reacts vigorously with fluoride and chlorate. Avoid contact with aluminum or zinc.		With Water: No reaction; soluble	
Classification: Poisonous liquid		Containers/Materials: Plastic (poly) drums		Odour: Odourless		With Common Materials: Contact with reducing agents will liberate arsenic (AsH_3), a colorless, highly toxic gas. Reacts vigorously with fluoride and chlorate. Avoid contact with aluminum or zinc.	
Shipping State: Liquid concentrate		Storage Temperature: Ambient		Molecular Weight: 150.9 ($AsO_4^{3-} \cdot 2H_2O$) Specific Gravity: 1.8-2.0		Stability: Stable	
Vapour Pressure: No available information		Boiling Point: 160°C		Vapour Density: No information		Extinguishing Data: Liquid is non-flammable. Most extinguishing agents can be used on fires involving arsenic acid.	
Solubility: Freely soluble (water)		Flash Point: Not flammable		Explosive Limits: Not applicable		Fire Behaviour: Liquid not flammable. At high temperatures, the liquid will volatilize, releasing toxic fumes.	
Floatability: Sinks and dissolves in water						Ignition Temperature: Not flammable	
						Burning Rate: Not applicable.	

TABLE 3.2 PHYSICAL AND CHEMICAL PROPERTIES OF PENTACHLOROPHENOL SOLIDS

Identification													
Common Name: Chlorophen	Penta PCP	Manufacturers:	<ul style="list-style-type: none"> Vulcan Materials Co. (Birmingham, Alabama) Rhône-Poulenc (Paris, France) Dynamit-Nobel (Germany) (ceased production in 1986) 										
Synonyms: Cryptogyl 01													
(past and current)	Santobrite 7												
Dowicide 7													
Dowicide G													
Penchlorol													
Transportation and Storage Information													
Shipping State: Solids (Blocks, flakes, prills)		Storage Temperature: Ambient	Labels and classification: Check with the Department of Transport										
Concentration: 96% by weight total (technical grade) chlorophenols (86% PCP)		Inert Atmosphere: No requirement											
Classification: Poisonous		Venting: Open											
Containers/Materials: Bags or solid blocks with polyethylene wrap													
Physical and Chemical Properties													
Physical State: Solid		Floatability: Sinks in water	Appearance: White to light brown solid										
Solubility: Freely soluble (oil)		Specific Gravity: 1.98 (22°C)											
		Vapour Pressure: 0.00011 mm Hg (20°C)											
		40 mm Hg (211°C)											
		Boiling Point: Decomposes at 310°C											
		Odour: Strong pungent odour when heated											
		Vapour Density: 9.2											
Hazard Data													
Extinguishing Data:	Use water spray, dry chemical, foam or carbon dioxide. (Note: fire residues may contain chlorinated furans or dioxins, and must be treated as contaminated). Use water to cool fire-exposed containers.												
Fire Behaviour:	When heated to decomposition, toxic fumes of hydrogen chloride are formed.												
Ignition Temperature:	Chlorinated dioxins may be generated.												
Burning Rate:	Not combustible												
With Water: No reaction													
With Common Materials: Can cause rapid deterioration of rubber when dissolved in oil.													
Reactivity													
Stability: Stable													

TABLE 3.2 PHYSICAL AND CHEMICAL PROPERTIES OF ACA SOLUTION

Identification		Transportation and Storage Information		Physical and Chemical Properties		Hazard Data	
Common Synonyms:	Chenonite ACA Ammoniacal copper arsenate	Manufacturers:	Prepared on-site from copper oxide and arsenic acid provided by J.H. Baxter and Co. (San Mateo, CA) and aqua ammonia from local suppliers.	Prepared State:	Treating solution prepared on-site (not transported).	Storage Temperature:	Ambient
Concentration:	Concentrate, 8 to 12% (by wt. as oxides)	Hoses:	PVC, rubber, polyethylene steel or stainless steel fittings only	For labels and classification:	Check with the Department of Transport		
Classification:	Working solution, 2 to 4% Poisonous, corrosive liquid	Venting:	Provide scrubbing to meet air discharge regulatory requirements	Containers/Materials:	Plastic, steel, or steel polylined		
Physical State:		Floatability:		Colour:	Light blue	With Water: No reaction; soluble	
Density:		Freezing Point:		Odour:	Sharp, characteristic odour (50 ppm threshold)	With Common Materials: Copper, tin, zinc alloys are readily corroded. Reacts with acrolein, acrylic acid, chlorosulphonic acid, dimethyl sulphate, halogens, hydrochloric acid, hydrofluoric acid, nitric acid, sulphuric acid, oleum, propylene oxide and silver nitrate. Avoid contact with aluminium or zinc.	
Vapour Pressure:		Explosive Limits:		pH:	2% solution 10.2 8% solution 12.0	Reactivity	
Solubility:		Mixtures of ammonia in air (16-25% by volume) in an enclosed space can ignite or explode if sparked or exposed to temperatures exceeding 650°C (1200°F)		Stability:	Stable	Ignition Temperature: Not flammable as liquid; ammonia is flammable at 649°C.	
Fire:		Extinguishing Data: Liquid is non-flammable. Most extinguishing agents can be used on fires involving ammonium hydroxide and arsenic acid.		Burning Rate:	Not applicable	Burning Rate: Not applicable	
Fire Behaviour:		Liquid not flammable. Mixtures of ammonia and air can ignite or explode (see above). When exposed to fire, the liquid solution releases ammonia gas and arsenic fumes.		Reactivity:	Reactivity	Reactivity	

TABLE 3.5 PHYSICAL AND CHEMICAL PROPERTIES OF COPPER OXIDE

Identification		Transportation and Storage Information	
Common Synonyms: Cuprous oxide	Manufacturers: Supplied by J.H. Baxter and Co. (San Mateo, CA)		
Concentration: 97% by weight purity	Shipping State: Solid	Storage Temperature: Ambient	Labels: Not regulated
Classification: Not regulated	Venting: No requirement	Containers/Materials: Steel drums	
Physical and Chemical Properties			
Physical State: Solid (20°C, 1 Atm)	Melting Point: 1235°C	Colour: Reddish-brown	
Molecular Weight: 193	Boiling Point: 1300°C	Odour: Odourless	
Specific Gravity: 5.75-6.09 (20°C)	Vapour Density: Not applicable		
Solubility: 0.02 milligrams/100 mL (water/20°C)	Vapour Pressure: Not applicable		
Floatability: Sinks in water	Flash Point: Not flammable		
	Explosive Limits: Not generally applicable - dust can explode under some conditions.		
Hazard Data			
Fire	Extinguishing Data: Solid is non-flammable	With Water: No reaction	
	Fire Behaviour: Solid is not flammable	With Common Materials: Reacts violently with acetylene, ammonium nitrate, bromates, chlorates, iodates, chlorine, ethylene oxide, fluorine, hydrogen peroxide and hydrogen sulphide.	
	Ignition Temperature: Not flammable	Reactivity	
	Burning Rate: Not applicable	Stability: Stable	

TABLE 3.3 PHYSICAL AND CHEMICAL PROPERTIES OF CREOSOTE

Identification	
Common: Creosote oil	Manufacturers: • Domtar Chemicals Group, Hamilton, Ontario
Synonyms: Coal tar creosote	• Currie Products, Hamilton, Ontario
(past and current)	• Allied Chemical Corporation, Detroit, Michigan
CAS Registry Number: 8001-58-9	• Koppers Company Inc., Pittsburgh, Pennsylvania
Transportation and Storage Information	
Shipping State: Liquid	Inert Atmosphere: No requirement
Chemical Family: Coal tar distillate	Venting: Open (flame arrestor)
Classification: Combustible	Containers/Materials: Tankers, tank cars, tank trucks: steel
Storage Temperature: Ambient	
Physical and Chemical Properties	
Physical State: Liquid	Specific Gravity: 1.05 - 1.09 at 15°C
Solubility: Practically insoluble in water. Soluble in alcohol, benzene and toluene.	Vapour Pressure: Variable
Floatability: Sinks in fresh and marine waters)	Boiling Point: 200 - 450°C
	Odour: Acrid, tarry aromatic
	Vapour Density: Variable (typically 3 to 5)
Hazard Data	
Fire	Extinguishing Data: Use dry chemical, foam or carbon dioxide. Use water to cool fire-exposed containers.
	Reactivity
	With Water: No reaction, insoluble With Common Materials: May react with oxidizing agents or strong acids. Stability: Stable
Fire	Fire Behaviour: Forms irritating heavy black smoke.
	Ignition Temperature: Variable, typically 400°C
	Burning Rate: 4 mm/min.

Summary of Toxicity Data on Antisapstain Products (Health and Welfare Canada)

This table should only be used in conjunction with the status reports available on each of these antisapstain products

Acute Toxicity	Azaconazole	Copper-8-quino-Linolate	Didecyldimethyl ammonium chloride (DDAC)	3-iodo-2-propynyl butyl carbamate (IPBC)	Borax ³	2-(thiocyanomethylthio) benzothiazole (TCMB)
Oral: Rat	Moderately toxic LD ₅₀ =308 mg/kg	Moderately toxic LD ₅₀ =4700 mg/kg f=3900 mg/kg	Moderately toxic LD ₅₀ =450 mg/kg	Low toxicity LD ₅₀ -M=1795 mg/kg f=1050 mg/kg LD ₅₀ -1580 mg/kg	LD ₅₀ ,3000 mg/kg	Moderately toxic LD ₅₀ -M=556 mg/kg f=702 mg/kg
Mouse	No data required	LD ₅₀ -M=9000 mg/kg f=7100 mg/kg	No data required	No data required	No data required	LD ₅₀ -M=2665 mg/kg f=2538 mg/kg
Rabbit	LD ₅₀ =324 mg/kg	No data required	No data required	No data required	No data required	No data required
Dermal:						
Rabbit	No data required	LD ₅₀ ,2000 mg/kg	LD ₅₀ ,2000 mg/kg	LD ₅₀ ,2000 mg/kg	No data required	LD ₅₀ ,2500 mg/kg
Rat	LD ₅₀ ,3100 mg/kg	No data required	No data required	No data required	No data required	No data required
Inhalation:						
Rabbit	LC ₅₀ ,0.06 mg/L (5% in water dilutable concen- trate)LC ₅₀ ,0.04 mg/L (1% in oil miscible liquid)	LC ₅₀ ,0.82 mg/L of air	No data ¹	No adequate data ²	No data required	No data
Rat	(4 hour exposure)					

¹"No data" means that no studies or information from the literature of registrant were available for evaluation.

²"No adequate data" means that data was submitted/available but was found inadequate/incomplete for evaluation - refer to individual status report for more details.

³Borax: all data on this active comes from the literature.

Summary of Toxicity Data on Antisapstain Products (Health and Welfare Canada)

Azaconazole	Copper-8-quino-linolate	Didecyldimethyl ammonium chloride (DDAC)	3-Iodo-2-propynyl butyl carbanate (IPBC)	Borax	2-(thiocyanato-methylthio) benzothiazole (TCMTB)
Irritation					
Eye: Rabbit	Non irritant	Mild irritant	Extremely severe irritant	Severe irritant	Moderate irritant
Dermal: Rabbit	Minimal irritant	No data	Severe irritant	Minimal irritant	Non irritant
Sensitization	Non-sensitizer	No data	Study submitted, and under review.	Non-sensitizer	No data
					Strong dermal sensitizer in laboratory animals.
					Potential skin sensitizer in human

Summary of Toxicity Data on Antisapstain Products (Health and Welfare Canada)

Araconazole	Copper-8-quino-lonolate	Didecyldimethyl ammonium chloride (DDAC)	3-Iodo-2-propynyl butyl carbamate (IPBC)	Borax	2-(thiocyanato-methylthio) benzothiazole (TCMB)
<hr/>					
Short Term Toxicity					
Oral: Rat	No data	No adequate data	90-day study submitted. Under review.	Effects on liver hepatocytes and fore-stomach lesions at 125 mg/kg/day; effects reduced on liver weight at 50 mg/kg/day. NOEL set at 20/mg/kg/day.	Potential adverse reproductive and haematological effects reduced spermiogenesis, testicular atrophy, reproductive failure, sterility (both sexes - rats).
Dog	Elevated alkaline phosphatase and liver histopathology	No data required	No adequate data	No data	Same as rat; plus decreased food consumption growth retardation, declined haemoglobin and erythrocytes, reduced vIt.B₂ binding to serum protein and arginase inhibition in red blood cells.
Chronic Toxicity and Oncogenicity				90-day dermal (Rat) study submitted.	Studies initiated for submission in 1990
				Under review.	No indication of carcinogenic effects from published information in laboratory animals.
					No data on chronic effects.

Summary of Toxicity Data on Antisapstain Products (Health and Welfare Canada)

	Araconazole	Copper-8-quino-lonolate	Didecyldimethyl ammonium chloride (DDAC)	1-iodo-2-propynyl butyl carbamate (IPBC)	Borax	2-(thiocyanatoethylthio) benzothiazole (TCMTB)
800 ppm. NOEL for chronic toxicity set at 200 ppm.	Effects were noted in a rat 2 year chronic study. A NOEL could not be set.	Effects were noted in a 2 year dog study. A NOEL could not be set.	No evidence of effects on reproductive parameters (fertility index, pup survival, pup weights, sex ratio gross abnormalities) in a multigeneration reproduction study in rats.	In a 2 generation rat reproduction study, a slight increase in number of stillborn pups was noted in both generations at 750 ppm (high dose) with a slight increase in resorptions in the second generation.	No data - see short-term section for reproductive effects noted in literature. Sponsor did not submit any studies on reproduction but such studies exist in the literature.	No adequate data
Reproductive toxicity	No adequate data	Study initiated				
Teratogenicity: Rat	NOEL for teratogenicity set at 60 mg/kg/day NOEL of 10 and 40 mg/kg/day set for maternal toxicity and fetotoxicity respectively.	Study to be submitted December 1991	No terata noted, a NOEL for teratogenicity was set at 125 mg/kg/day and a NOEL for maternal and fetotox was set at 50 mg/kg/day	No indication of teratogenic effects in laboratory animals from published data.	No adequate data	

Summary of Toxicity Data on Antisapstain Products (Health and Welfare Canada)

Azaconazole	Copper- β -quino-lonolate	Didecyldimethyl ammonium chloride (DDAC)	3- <u>Iodo</u> -2-propynyl butyl carbamate (IPBC) (TCMB)
Rabbit	NOEL for teratogenicity and fetotoxicity set at 160 mg/kg/day. NOEL of 80 mg/kg/day set for maternal toxicity.	Study submitted. Scheduled for review. Under review.	Study submitted. Same as above.
Mutagenicity	Negative in Ames, mouse micro-nucleus, and chromosome aberration in human peripheral lymphocytes. DNA repair of primary rat hepatocytes. SOS chromotest in <u>E.coli</u> and sex linked recessive lethal in ♀. melanogaster tests.	Slight positive in "in vitro" microbial assay.	Negative in Ames test
		Negative in bone marrow cytogenetic in rats	No mutagenic effects in published literature
		Negative in rat micronucleus test	Negative in CHO sister chromatid exchange.
		Negative in mouse micronucleus assay.	Negative in unscheduled synthesis in rat hepatocytes.
		Negative in mouse micronucleus assay.	Negative in mouse micronucleus assay.
Pharmacokinetics	90% dose excreted in 24 hours. Radioactivity in liver, kidney and plasma. Excretion through urine/feces (55/45%) as conjugates.	50% of oral dose absorbed. 83.9% excreted through urine and feces in 24 hour. No radioactivity in tissues after 96 hours	80% of dose excreted in urine within 24 hours. 97.2% of dose excreted in 96 hours (urine, feces, cage wash).
		Study initiated	Target organs (radioactivity detected) are kidney and liver, fat, to a lesser degree skeletal muscle and skin. Levels declined over 10 days.
			Labelled IPBC was rapidly and completely metabolized to $^{14}\text{CO}_2$ and other polar components.

Summary of Environmental Data on Antisapstain Products (Environment Canada)

This table should only be used in conjunction with the status reports available on each of these antisapstain products

	Azaconazole	Copper-8-quino-linolate	Diacyldimethyl ammonium chloride (DDAC)	3-iodo-2-propynyl butyl carbamate (IPBC)	2-(thiocyanomethylthio) benzothiazole (TCMTB)
Volatilization.	Should not volatilize from water	Low vapour pressure (0.0133 Pa at 20°C); very low solubility	Not volatile; highly soluble in water. Volatilization not a dissipation route (<220 ug/L. Should not volatilize from moist surfaces)	Low vapour pressure (about 0.002 Pa); moderate solubility in water (about 156 mg/L). Volatilization not a dissipation route	Not volatile; very soluble in water. Vaporization not a dissipation route
Hydrolysis	Chemical hydrolysis should not be a mechanism for dissipation in an aquatic environment	Does not hydrolyze between pH's 2.7 and 12; stable to hydrolysis in the environment (*)	No report submitted (": December 1989)	Reported not to hydrolyze (test conditions not reported) (": October 1990)	In water, sodium tetraborate pentahydrate hydrates to the dehydrate
Phototransformation	May be photolabile (* on wood; May 1990)	Stable in visible and UV light (*)	No report submitted (": December 1989)	No report submitted	Rapid (DT50 <1 day); yields mercaptobenzothiazole in water

* Registrant committed to submitting study report (with expected date of submission, if known).

Summary of Environmental Data on Antisapstain Products (Environment Canada)

This table should only be used in conjunction with the status reports available on each of these antisapstain products.

	Azaconazole	Copper-8-quino-linolate	Didecyldimethyl ammonium chloride (DDAC)	3-iodo-2-propynyl butyl carbamate (IPBC)	Borax	2-(thiocyanato-methylthio) benzothiazole (TMTB)
Adsorption/ desorption, leaching in soil	Moderately strongly to strongly adsorbed to soils given its persistence, may eventually leach	No report submitted (* for both adsorption/desorption and leaching)	Probably adsorbed to organic material (* for adsorption/desorption; December 1989)	No report submitted (* for adsorption/desorption; October 1990)	No report submitted (* for adsorption/desorption; October 1990)	Moderately to strongly adsorbed to soils; low mobility in most soils, mobile in sand.
Biotransformation	DT ₅₀ of about one year (aerobic soil lab studies) indicates persistence (* aerobic aquatic; December 1989)	No report submitted (*)	Probably major route of dissipation, with rapid complete transformation (*; June 1990)	Little biotransformation; iodocarb is a powerful antimicrobial (*; October 1990)	Should not be transformed	Should not occur in aerobic sediment/water (*; June 1989)
Bioconcentration	Should not be a concern (log K _{ow} = 2.17)	May range from 0 for bluegill to 2000 for <i>Chlorella regularis</i>	Should not bioaccumulate (*; December 1989)	Bioconcentration factors of about 4 for carp	Should not occur	Should not bioaccumulate (*; June 1989)
Environmental toxicology	96-hour LC ₅₀ rainbow trout: 22 ppm chinook salmon: 27 ppm Additional information	6-hour LC ₅₀ <i>Daphnia</i> >300 ppm 96-hour LC ₅₀ : Cu-8: guppies: 0.180 ppm Cu-8 (solubilized): guppies: 0.001 ppm	96-hour LC ₅₀ rainbow trout: 0.68-0.80 ppm chinook salmon: 1.06-1.11 ppm Growth inhibition probable for algae	96-hour LC ₅₀ rainbow trout: 0.31 ppm bluegill sunfish: 1.24 ppm. Dietary LC ₅₀ >3000 ppm for	No report submitted.	Very toxic to fish 96-hour LC ₅₀ rainbow trout: 0.039-0.054 ppm chinook salmon: 0.015-0.018 ppm

Summary of Environmental Data on Antisapstain Products (Environment Canada)

This table should only be used in conjunction with the status reports available on each of these antisapstain products

	Azaconazole	Copper-8-quino-linolate	Didecyldimethyl ammonium chloride (DDAC)	3-iodo-2-propynyl butyl carbamate (IPBC)	Borax	2-(thiocyanomethylthio) benzothiazole (TCMTB)
Leaching from wood	No report submitted (*)	No report submitted	No report submitted	No report submitted	No report submitted; likely given water solubility	No report submitted; No report submitted
Disposal of treated wood	No report submitted	No report submitted (*)	Incineration safe (produces CO ₂ , CO, NH ₃ , NO _x , HCl)	No report submitted	No report submitted. Arsenic reported as microcontaminant	Incineration in hog-fuel boiler safe (SO ₂ produced); no potential for dioxin or furan production
Stormwater concentration (proposed B.C. regulation)	No report available	300 ppb-effective date will be announced when the regulation is promulgated	No report available	No report available	No report available	300 ppb-effective date will be announced when the regulation is promulgated 15 ppb (1989-09-01)

Summary of Toxicity Data on Antissapstain Products (Department of Fisheries and Oceans)

This table should only be used in conjunction with the status reports available on each of these antissapstain products

	Azaconazole	Copper-8-quino-linolate	Diacyldimethyl ammonium chloride (DDAC)	3-iodo-2-propynyl butyl carbamate (IPBC)	2-(thiocyanomethylthio) benzothiazole (TCMTB)
Biological Effects					
Acute toxicity to fish	96 hour LC ₅₀ - bluegill 32 mg/L (20°C)	48 hour LC ₅₀ - rainbow trout 500 ug/L (20°C)	48 hour LC ₅₀ - catfish 4.8 ppm - bluegill 0.75 ppm	96 hour LC ₅₀ - bluegill 1.24 mg/L (18°C)	96 hour LC ₅₀ - bluegill 0.047 mg/L (60% TCMTB)
	- bluegill 14 mg/L (14°C)	- Harlequin fish 900-1400 ug/L (20°C)	96 hour LC ₅₀ - catfish 2.6 ppm (14°C)	- rainbow trout 0.31 mg/L (12°C)	- rainbow trout 0.029 mg/L
	- carp 17 mg/L (14°C)	96 hour LC ₅₀ - rainbow trout 7.5-15.1 ug/L	48 hour LC ₅₀ - bluegill 0.59 ppm (14°C)	- rainbow trout 0.130 mg/L (Busan 1030)	- rainbow trout 0.130 mg/L (Busan 1030)
	- catfish 37 mg/L (22°C)	- chinook salmon 26.9 ug/L (prelim. EPS data)	- orange-red kilifish 0.354 mg/L	- chinook salmon 0.055 mg/L (30% TCMTB)	- chinook salmon 0.165 mg/L (Busan 30 MP)
	- golden orf 30 mg/L (22°C)	- rainbow trout 1.24 ppm	- rainbow trout 0.88 ppm (EPS data)	- rainbow trout 0.015 mg/L (30% TCMTB)	- chinook salmon 0.015 mg/L (30% TCMTB)
	- brown trout 22 mg/L (14°C)				96 hour LC ₅₀ MBF - bluegill - 1.50 mg/L
Severe nervous disorders					- rainbow trout - 0.75 mg
In survivors (all species)					- rainbow trout
Additional fish data received					0.73 mg/L (flowthrough)
Chronic-exposure sub-lethal toxicity to fish	Data received 29 May 1989	No data	No data	No data	No data

• "No data" means that no information was available from either the data package submitted by the product's registrant or from the literature available in DFO files.

Summary of Toxicity Data on Antisapstain Products (Department of Fisheries and Oceans)

This table should only be used in conjunction with the status reports available on each of these antisapstain products

Kow value	Log Kow = 2.17	No data	No data	No data	25 (log Kow = 1.40; = 2.42 for MDT)
Bioconcentration in fish	Data received 29 May 1989	No data	Study initiated 8CF less than 4.5 in Japanese carp	No data	No data
Acute toxicity to invertebrates	48 hour LC50 Daphnia magna 86 mg/L (20°C). Additional data received 29 May 1989	No LC50 for Daphnia magna but 21% mortality at 1000 mg/L after 6 hours and 14% mortality at 3000 mg/L after 6 hour (max. tested)	No data	No data	48 hour EC50 - Daphnia pullex 0.06 mg/L (60X TCMTB)
Chronic-exposure, sub-lethal toxicity to invertebrates	No data - But severe nervous disorders observed at ≥ 3.2 mg/L in acute studies	No data	No data	No data	No data
Effects upon phytoplankton and aquatic macrophytes	No data	No data	No data	No data	No data for TCMTB - MDT appears to have low toxicity to algae but concentration & spp. not reported

Summary of Toxicity Data on Antisapstain Products (Department of Fisheries and Oceans)

This table should only be used in conjunction with the status reports available on each of these antisapstain products

	Araconazole	Copper-8-quinolinolate	3-iodo-2-propynyl butyl carbamate (IPBC) (DDAC)	2-(thiocyanomethylthio) benzothiazole (TCMTB)
Mobility in Aquatic Systems				
Water solubility	300 mg/L	No data	Soluble	170-232 mg/L at 24°C 20-30°C
Vapour pressure	8.6×10^{-6} Pa (20°C)	No data	No data	2×10^{-3} Pa No data
Soil adsorbance/ desorption	Freundlich Constant = 6.56 (20-22°C) Strongly adsorbed to soil; esp. high organic/low pH and temp. Desorption data received 29 May 1989	Study initiated October 1990	Data to be submitted October 1990	No data
Leaching from wood	No data	No data	No data	No data
Leaching through soil	Rel. non-mobile 4.6 cm (15 cm) max. - pH 3.9 - 7.0 30 cm rainfall - organic 1.13 - 7.87%	No data	No data	No data
Persistence in soil	T 1/2 = 355 d. Anaerobic soil transformation study received 29 May 1989	No data	No data	Data to be submitted October 1990
				T 1/2 = 23 hour (lab studies)

Summary of Toxicity Data on Antisapstain Products (Department of Fisheries and Oceans)

This table should only be used in conjunction with the status reports available on each of these antisapstain products

	Azaconazole	Copper-8-quino-linolate	Didecyldimethyl ammonium chloride (DDAC)	3-iodo-2-propynyl butyl carbamate (IPBC)	Borax	2-(thiocyanomethylthiobenzothiazole (TCMTB))
Fate and Persistence in Aquatic Systems						
Hydrolysis	Data received 29 May 1989	No data	Study initiated	No data (Incidental info. suggests no hydrolysis)	N/A	No data for TCMTB - H stable (no confirming data)
Photolysis in water	Data received 29 May 1989	No data	Study initiated	No data (Incidental info. suggests no photolysis)	N/A	No data for TCMTB - H will photolyze (no confirming data)
Persistence in water	Aerobic aquatic transformation data to be submitted December 1989	No data	Study initiated	<7 days - Due to microbial activity (lab studies)	No data	T _{1/2} = 15 d. (preliminary study) - 1% of HBT do in water after 31 d. (aerobic)
Rate in aquatic environments	No data	No data	Study initiated	No data	No data	No data
Predicted Environmental Concerns	Not possible	Not possible	pending completion of studies	Not possible	Not possible	Not possible
Analytical methodology - Environmental Residues	Yes - to have been used in fish toxic tests, but results were not submitted	None	No data	No data	Presumably yes	Available, but questionable

Summary of Toxicity Data on Antisapstain Products (Department of Fisheries and Oceans)

This table should only be used in conjunction with the status reports available on each of these antisapstain products

Risk Assessment	Risk to Fishery Resources	Unassessable	Unassessable	Unassessable	Unassessable
Araconazole	Copper-8-quino-lonolate	Diidodecyl dimethyl ammonium chloride (DDAC)	3- <i>iodo</i> -2-propynyl butyl carbamate (IPBC)	Borax	2-(thiocyanomethylthiobenzothiazole (TCMTB)

APPENDIX IV

ASME POWER TEST CODE

Steam Generating Units

POWER
TEST
CODES

FOREWORD

THE Test Code for Stationary Steam-Generating Units was one of the group of ten forming the 1915 Edition of the ASME Power Test Codes. A revision of these codes was begun in 1918 and the Test Code for Stationary Steam-Generating Units was reissued in revised form in October, 1926. Further revisions were issued in February, 1930 and January, 1936.

In October, 1936 the standing Power Test Codes Committee requested PTC Committee No. 4 to consider a revision of the Code to provide for heat balance tests on large steam generating units. In rewriting the Code advantage was taken of the experience of the several companies in the utility field which had developed test methods for the large modern units including the necessary auxiliary equipment directly involved in the operation of the units. At the same time the needs of the small installations were not overlooked. At the November 30, 1945 meeting of the standing Power Test Codes Committee, this revision was approved and on May 23, 1946 the Code was approved and adopted by the Council.

In view of the continuously increasing size and complexity of steam generating units, it was obvious that changes were required in the 1946 Edition of the Test Code. In May, 1958 the technical committee was reorganized to prepare this revision. The completely revised Code, the Test Code for Steam Generating Units, was approved by the Power Test Codes Committee on March 20, 1964. It was further approved and adopted by the Council as a standard practice of the Society by action of the Board on Codes and Standards on June 24, 1964.

December, 1964

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ASME POWER TEST CODES

Test Code for Steam Generating Units

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SECTION 0, INTRODUCTION

0.1 This Code contains instructions for testing steam generating units. These units are defined as combinations of apparatus for liberating and recovering heat, together with apparatus for transferring to a working fluid the heat thus made available. For the purpose of this Code, such a unit may include the boiler, furnace, superheater, reheater, economizer, air heater, and fuel-burning equipment. The economizer and air heater are not considered a part of the unit when the heat absorbed by them is not returned to the unit. It is not the intent of these testing procedures to obtain data for establishing design criteria of individual parts of the over-all steam generator. Code Supplements PTC 4.2 and PTC 4.3 cover testing of pulverizers and air heaters, respectively.

0.2 It is intended that in using this Code a detailed examination will be made of the Code on General Instructions PTC 1 and all other Codes herein referred to before starting preparations for the tests. Such study is for the purpose of assuring an orderly and thorough testing procedure since it provides the user with an over-all understanding of the ASME Power Test Codes requirements and enables him to understand readily the interrelationship of the various Codes. Care should be exercised to obtain and use the latest revisions of the Codes.

0.3 While Section 2 of this Code is concerned with symbols and their descriptions applying specifically to testing of steam generating units, the user is referred to the Code on Definitions and Values PTC 2 for a more complete discussion of the items which will be encountered.

0.4 The Supplements on Instruments and Apparatus PTC 19 referred to herein should be studied thoroughly because the value of the test results depends on the selection and application of the instruments, their calibration and the accuracy of the readings.

0.4.1 Other items of vital importance to the value of the test are the proper determination of the high-heat value and other properties of the fuel used. The appropriate Code for the type of fuel

burned and ASTM Standard Method pertaining to Heat of Combustion should be followed carefully.

0.5 This Code is intended as a guide for the conduct of all steam generator tests, but it could not possibly detail a test applicable to every variation in the design of steam generators. In every case a competent engineer must study the particular unit and its relation with the rest of the cycle and develop test procedures which are in agreement with the general accuracy and intention of this Code. Examples of the design variations in operation at the time of preparation of this Code are subcritical and supercritical once-through units and dual-cycle steam generators. Such units were considered as the Code was being prepared and it is believed that the provisions herein can be applied to the testing of such steam generators.

0.6 The general instructions contained in this Code shall also apply to the testing of high temperature water heaters, except that efficiency determination shall be by heat loss method only, as described in Section 5. The input-output method is not acceptable because of potentially large inaccuracies introduced by the presence of indeterminant quantities of steam in the output and by the small temperature measurement errors in a large volume flow output.

Test capacity or output shall be determined from measured heat input and efficiency, or by direct measurement of heat output if a high degree of accuracy is not required.

0.7 The testing of nuclear and combined-cycle steam generators were not included because their development at the time of revising this Code was such that specific recommendations could not be made.

0.8 Advanced instrument systems, such as those using electronic devices or mass flow techniques, may, by mutual agreement, be used as alternates to the mandatory Code instrument requirements, provided that the application of such instruments has demonstrated accuracy equivalent to that required by this Code.

SECTION 1, OBJECT AND SCOPE

1.01 The purpose of this Code is to establish procedures for conducting performance tests to determine:

1.01.1 Efficiency

1.01.2 Capacity

1.01.3 Other related operating characteristics such as steam temperature and control range, exit gas temperature, draft loss, steam - water - and air - pressure drops, solids in steam and air leakage.

1.02 A determination of any or all of the performance items specified above may be necessary for other purposes such as:

1.02.1 Checking the actual performance against guarantee.

1.02.2 Comparing these items with a standard of operation.

1.02.3 Comparing different conditions or methods of operation.

1.02.4 Determining the performance of different parts of the steam generating unit.

1.02.5 Comparing performance when firing different fuels.

1.02.6 Determining the effects of changes to equipment.

1.03 The rules and instructions given in this Code apply to the equipment defined in the introduction. Testing of auxiliary apparatus shall be governed by the Power Test Code applying specifically to the auxiliary in question.

1.04 Instructions are given for two acceptable methods of testing steam generators to determine efficiency. One method is the direct measurement of input and output, hereinafter referred to as the input-output method. The other method is the direct measurement of heat losses and is herein-after referred to as the heat loss method. The method followed in conducting the tests shall be clearly defined in the report.

1.04.1 The input-output method requires the accurate measurement of the quantity and high-heat value of the fuel, heat credits and the heat absorbed by the working fluid or fluids.

1.04.2 The heat loss method requires the determination of losses, heat credits and ultimate

analysis and high-heat value of the fuel. To establish the capacity at which the losses occur it is necessary to measure either the input or output.

1.04.3 Throughout this Code, input is defined as the chemical heat in the fuel (high-heat value of the fuel as determined from laboratory analysis) plus heat credits added to the working fluid or fluids, air, gas and other fluid circuits which cross the envelope boundary as shown in Fig. 1.* The envelope boundary encompasses the equipment to be included in the designation "steam generating unit." Heat input and output that cross the envelope boundary are involved in the efficiency calculations. Apparatus is outside the envelope boundary when it requires an outside source of heat or where the heat exchanged is not returned to the steam generating unit.

1.04.4 The output is defined as the heat absorbed by the working fluid or fluids.

1.04.5 Heat credits are defined as those amounts of heat added to the envelope of the steam generator unit other than the chemical heat in the fuel "as fired". These credits include quantities such as sensible heat (function of specific heat and the measured temperature) in the fuel, in the entering air and in the atomizing steam, and heat from power conversion in pulverizer, circulating pump, primary air fan and recirculating fan.

1.04.6 For a better understanding of the relationships between input, output, credits and losses, refer to Fig. 2.*

1.05 Capacity of steam generators is defined as actual evaporation in pounds of steam per hour delivered or Btu per hour absorbed by the working fluid or fluids. Capacity of hot water heaters is defined as the heat absorbed by water and the heat of any steam that may be generated (Btu per hour).

1.06 The efficiency of steam generating equipment determined within the scope of this Code is the gross efficiency and is defined as the ratio of heat absorbed by the working fluid or fluids to the heat input as defined in Par. 1.04.3. This definition disregards the equivalent heat in the power

*Note: Figs. 1 and 2 are available in pad form through the ASME Order Department.

required by the auxiliary apparatus external to the envelope (See Fig. 1).

1.06.1 Efficiency for the two methods is expressed by the following equations:

Input-Output Method -

$$\text{Efficiency (per cent)} = \frac{\text{Output}}{\text{Input}}$$

$$= \frac{\text{Heat absorbed by working fluid or fluids}}{\text{Heat in fuel + heat credits}} \times 100$$

For derivation see Par. 7.2

Heat Loss Method -

Efficiency (per cent)

$$= 100 - \left(\frac{\text{Heat Losses}}{\text{Heat in fuel + Heat Credits}} \times 100 \right)$$

For derivation see Par 7.3.

1.07 For conducting an abbreviated efficiency test that considers only the major losses, and only the chemical heat in the fuel as input, the data and calculation procedures in the ASME Test Report for Simplified Efficiency Test may be used. (Note: These forms are available in pad form through the ASME Order Department.)

The use of abbreviated test procedures are not encouraged, but it is recognized that on routine testing of all sizes of steam generators and on acceptance testing of small heating and industrial steam generators that a simplified test is the only practical approach. Although the abbreviated test procedure ignores the minor losses and heat credits, the test procedures for obtaining the major items will be the same as specified in PTC 4.1, Test Code for Steam Generating Units and therefore the contents of this Code should be read and understood prior to running a simplified effi-

ciency test. Where heat losses are to be adjusted to compensate for variations in fuel, or changes in inlet air temperature, as would be done in verifying an efficiency guarantee, the procedure given in Section 7, Corrections to Standard or Guarantee Conditions of the Code should be followed.

1.08 The adjustment of test results to include the effect of equivalent heat in auxiliary power to determine "net efficiency" is not a requirement of the Code. If net efficiency is to be determined, it shall be by the method given in Par. 6.2.

1.09 Both the heat loss and the input-output methods of this Code apply to steam generating units operating with either solid, liquid or gaseous fuels.

1.09.1 This Code will apply only when tests are run using a single fuel.

1.09.2 Where test have to be made using a combination of fuels, it will be necessary to establish test procedures and calculations based on the guiding principles and general intent of this Code. For assistance in approaching this problem reference is suggested to Volume 78, Transactions ASME, August, 1956 "Combustion Calculations for Multiple Fuels."

1.10 The determination of data of a research nature or other special data is not covered by this Code.

1.11 It is recommended that a report be prepared for each test, either the abbreviated or complete test, giving complete details of the conditions under which the test has been made including a record of test procedures and all data in form suitable for demonstrating that the objectives of the test have been attained.

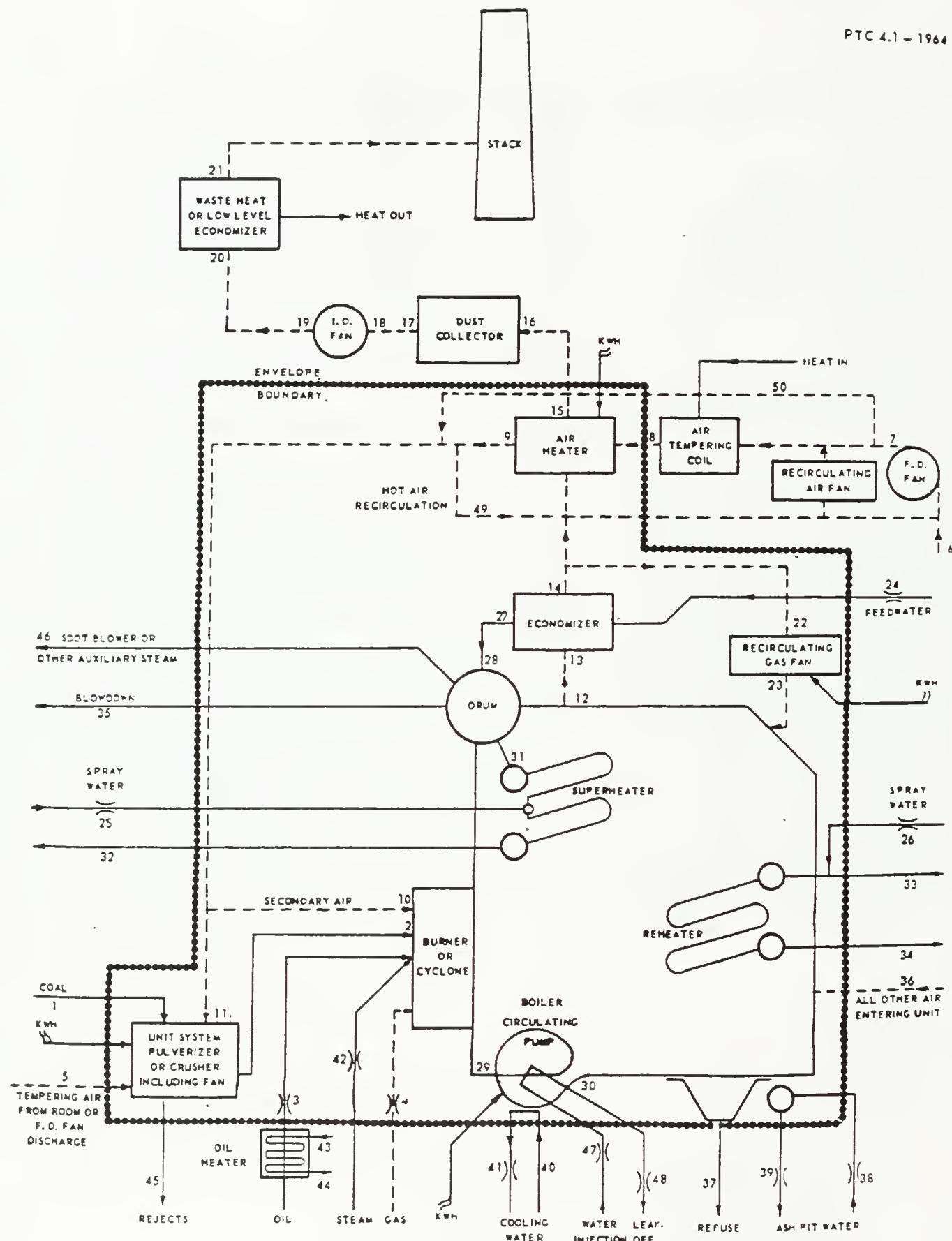


FIG 1 STEAM GENERATING UNIT DIAGRAM

HEAT IN FUEL (H_f) (CHEMICAL)

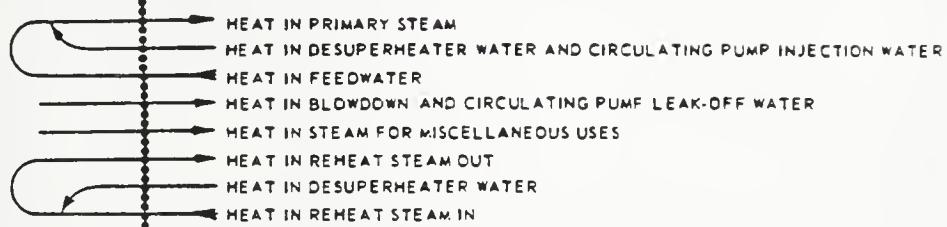
PTC 4.1 - 1964

INPUT

- B_A HEAT IN ENTERING AIR
- B_z HEAT IN ATOMIZING STEAM
- B_f SENSIBLE HEAT IN FUEL
- B_x PULVERIZER OR CRUSHER POWER
- B_x BOILER CIRCULATING PUMP POWER
- B_x PRIMARY AIR FAN POWER
- B_x RECIRCULATING GAS FAN POWER
- B_{mA} HEAT SUPPLIED BY MOISTURE IN ENTERING AIR
- B_w HEAT IN COOLING WATER

+ CREDITS (B)

ENVELOPE
BOUNDARY



LOSSES (L)

- L_{UC} UNBURNED CARBON IN REFUSE
- L_G HEAT IN DRY GAS
- L_{mf} MOISTURE IN FUEL
- L_H MOISTURE FROM BURNING HYDROGEN
- L_{mA} MOISTURE IN AIR
- L_z HEAT IN ATOMIZING STEAM
- L_{CO} CARBON MONOXIDE
- L_{UH} UNBURNED HYDROGEN
- L_{UHC} UNBURNED HYDROCARBONS
- L_B RADIATION AND CONVECTION
- L_p RADIATION TO ASH PIT, SENSIBLE HEAT IN SLAG & LATENT HEAT OF FUSION OF SLAG
- L_d SENSIBLE HEAT IN FLUE DUST
- L_r HEAT IN PULVERIZER REJECTS
- L_w HEAT IN COOLING WATER
- L_s SOOT BLOWING

$$\text{OUTPUT} = \text{INPUT} - \text{LOSSES}$$

$$\text{DEFINITION: EFFICIENCY (PERCENT)} = \eta_e (\%) = \frac{\text{OUTPUT}}{\text{INPUT}} \times 100 = \frac{\text{INPUT} - L}{H_f + B} \times 100$$

$$\text{HEAT BALANCE: } H_f + B = \text{OUTPUT} + L \text{ OR } \eta_e (\%) = \left[1 - \frac{L}{H_f + B} \right] \times 100$$

FIG. 2 HEAT BALANCE OF STEAM GENERATOR

**ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST**

PTC 4.1-a (1964)

JMMARY SHEET

		TEST NO.	BOILER NO.	DATE
OWNER OF PLANT		LOCATION		
TEST CONDUCTED BY		OBJECTIVE OF TEST		DURATION
BOILER MAKE & TYPE		RATED CAPACITY		
STOKER TYPE & SIZE				
PULVERIZER, TYPE & SIZE		BURNER, TYPE & SIZE		
FUEL USED	MINE	COUNTY	STATE	SIZE AS FIRED
PRESURES & TEMPERATURES				
1	STEAM PRESSURE IN BOILER DRUM	psia		COAL AS FIRED PROX. ANALYSIS
2	STEAM PRESSURE AT S. H. OUTLET	psia	37	MOISTURE
3	STEAM PRESSURE AT R. H. INLET	psia	38	VOL MATTER
4	STEAM PRESSURE AT R. H. OUTLET	psia	39	FIXED CARBON
5	STEAM TEMPERATURE AT S. H. OUTLET	F	40	ASH
6	STEAM TEMPERATURE AT R H INLET	F		TOTAL
7	STEAM TEMPERATURE AT R.H. OUTLET	F	41	Btu per lb AS FIRED
8	WATER TEMP. ENTERING (ECON) (BOILER)	F	42	ASH SOFT TEMP.* ASTM METHOD
9	STEAM QUALITY % MOISTURE OR P. P. M.			COAL OR OIL AS FIRED ULTIMATE ANALYSIS
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	43	CARBON
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	44	HYDROGEN
12	TEMPERATURE OF FUEL	F	45	OXYGEN
13	GAS TEMP. LEAVING (Boiler) (Econ.) (Air Htr.)	F	46	NITROGEN
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guaranteed)	F	47	SULPHUR
UNIT QUANTITIES		40	ASH	60 CO ₂
15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	37	MOISTURE
16	ENTHALPY OF (SATURATED) (SUPERHEATED) STM	Btu/lb		TOTAL
17	ENTHALPY OF SAT. FEED TO (BOILER) (ECON.)	Btu/lb		COAL PULVERIZATION
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	48	GRINDABILITY INDEX*
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	49	FINENESS % THRU 50 M ⁰
20	HEAT ABS LB OF STEAM (ITEM 16 - ITEM 17)	Btu/lb	50	FINENESS % THRU 200 M ⁰
21	HEAT ABS LB R. H. STEAM (ITEM 19 - ITEM 18)	Btu/lb	64	INPUT-OUTPUT EFFICIENCY OF UNIT %
22	DRY REFUSE (ASH F/T + FLY ASH) PER LB AS FIRED FUEL	lb/lb		HEAT LOSS EFFICIENCY
23	BTU PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	65	HEAT LOSS DUE TO DRY GAS
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	66	HEAT LOSS DUE TO MOISTURE IN FUEL
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	67	HEAT LOSS DUE TO H ₂ O FROM COMB. OF H ₂
HOURLY QUANTITIES		68	HEAT LOSS DUE TO COMBUST. IN REFUSE	
26	ACTUAL WATER EVAPORATED	lb/hr	69	HEAT LOSS DUE TO RADIATION
27	REHEAT STEAM FLOW	lb/hr	70	UNMEASURED LOSSES
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	71	TOTAL
29	TOTAL HEAT INPUT (Item 28 x Item 41) 1000	kB/hr	72	EFFICIENCY = (100 - Item 71)
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr		
31	TOTAL HEAT (Item 26 x Item 20) + (Item 27 x Item 21) + Item 30 OUTPUT 1000	kB/hr		
FLUE GAS ANAL. (BOILER) (ECON) (AIR HTR) OUTLET				
32	CO ₂	% VOL		
33	O ₂	% VOL		
34	CO	% VOL		
35	N ₂ (BY DIFFERENCE)	% VOL		
36	EXCESS AIR	%		

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

OWNER OF PLANT

TEST NO.

BOILER NO.

DATE

HEAT OUTPUT IN BOILER BLOW-DOWN WATER = LB OF WATER BLOW-DOWN PER HR X	ITEM 15	ITEM 17	kB/hr
	.....	.....	= 1000

If impractical to weigh refuse, this item can be estimated as follows

$$\text{DRY REFUSE PER LB OF AS FIRED FUEL} = \frac{\% \text{ ASH IN AS FIRED COAL}}{100 - \% \text{ COMB. IN REFUSE SAMPLE}}$$

$$\text{CARBON BURNED PER LB AS FIRED FUEL} = \frac{\text{ITEM 43}}{100} - \left[\frac{\text{ITEM 22}}{14.500} \times \text{ITEM 23} \right] = \dots$$

NOTE: IF FLUE DUST & ASH PIT REFUSE DIFFER MATERIALLY IN COMBUSTIBLE CONTENT, THEY SHOULD BE ESTIMATED SEPARATELY. SEE SECTION 7, COMPUTATIONS.

$$\begin{aligned} \text{DRY GAS PER LB AS FIRED FUEL BURNED} &= \frac{11\text{CO}_2 + 8\text{O}_2 + 7(\text{N}_2 + \text{CO})}{3(\text{CO}_2 + \text{CO})} \times (\text{LB CARBON BURNED PER LB AS FIRED FUEL} + \frac{3}{8} \text{S}) \\ &= \frac{11 \times \text{ITEM 32} + 8 \times \text{ITEM 33} + 7 \left(\text{ITEM 35} + \text{ITEM 34} \right)}{3 \times \left(\text{ITEM 32} + \text{ITEM 34} \right)} \times \left[\frac{\text{ITEM 24}}{\dots} + \frac{\text{ITEM 47}}{\dots} \right] = \dots \\ &\quad \text{267} \end{aligned}$$

$$\begin{aligned} \text{EXCESS AIR} &= 100 \times \frac{\text{O}_2 - \frac{\text{CO}}{2}}{.2682\text{N}_2 - (\text{O}_2 - \frac{\text{CO}}{2})} = 100 \times \frac{\text{ITEM 33} - \frac{\text{ITEM 34}}{2}}{.2682(\text{ITEM 35}) - (\text{ITEM 33} - \frac{\text{ITEM 34}}{2})} = \dots \end{aligned}$$

HEAT LOSS EFFICIENCY	Btu/lb AS FIRED FUEL	LOSS $\frac{\text{Btu}}{\text{HHV}} \times \frac{100}{100} =$	LOSS %
HEAT LOSS DUE TO DRY GAS = $\frac{\text{LB DRY GAS PER LB AS FIRED FUEL}}{\text{PER LB AS FIRED FUEL}} \times C_p \times (\text{LVG} - \text{Lair}) = \frac{\text{ITEM 25}}{\text{ITEM 13} - (\text{ITEM 11})} \times 0.24 = \dots$		$\frac{65}{41} \times 100 =$	.....
HEAT LOSS DUE TO MOISTURE IN FUEL = $\frac{\text{LB H}_2\text{O PER LB AS FIRED FUEL}}{\text{PER LB AS FIRED FUEL}} \times [(\text{ENTHALPY OF VAPOR AT 1 PSIA & T GAS LVG}) - (\text{ENTHALPY OF LIQUID AT T AIR})] = \frac{\text{ITEM 37}}{100} \times [(\text{ENTHALPY OF VAPOR AT 1 PSIA & T ITEM 13}) - (\text{ENTHALPY OF LIQUID AT T ITEM 11})] = \dots$		$\frac{66}{41} \times 100 =$	.....
HEAT LOSS DUE TO H_2O FROM COMB. OF $\text{H}_2 = 9\text{H}_2 \times [(\text{ENTHALPY OF VAPOR AT 1 PSIA & T GAS LVG}) - (\text{ENTHALPY OF LIQUID AT T AIR})]$ $= 9 \times \frac{\text{ITEM 44}}{100} \times [(\text{ENTHALPY OF VAPOR AT 1 PSIA & T ITEM 13}) - (\text{ENTHALPY OF LIQUID AT T ITEM 11})] = \dots$		$\frac{67}{41} \times 100 =$	.....
HEAT LOSS DUE TO COMBUSTIBLE IN REFUSE = $\text{ITEM 22} \times \text{ITEM 23} = \dots$		$\frac{68}{41} \times 100 =$	.....
HEAT LOSS DUE TO RADIATION = $\frac{\text{TOTAL BTU RADIATION LOSS PER HR}}{\text{LB AS FIRED FUEL} - \text{ITEM 28}} = \dots$		$\frac{69}{41} \times 100 =$	.....
UNMEASURED LOSSES ** = \dots		$\frac{70}{41} \times 100 =$	.....
TOTAL = \dots		\dots
EFFICIENCY = $(100 - \text{ITEM 71})$		\dots

rigorous determination of excess air see Appendix 9.2 - PTC 4.1-1964
losses are not measured, use ABMA Standard Radiation Loss Chart, Fig. 8, PTC 4.1-1964
measured losses listed in PTC 4.1 but not tabulated above may be provided for by assigning a mutually
read upon value for Item 70.

SECTION 2, SYMBOLS AND THEIR DESCRIPTIONS

2.1 Numerical Subscripts. The diagram of a steam generating unit, shown in Fig. 1, is intended to serve as a key to numerical subscripts employed throughout this Code to indicate the location to which reference is made. Many large installations will have all of the apparatus shown. Small industrial and commercial installations will be less elaborate. Even though the apparatus may not be in exactly the same relative position, it is believed that the numerical identification shown on this line diagram will prove applicable and helpful.

2.1.1 In the case of chemical symbols, the numerical subscripts refer to the number of atoms and not to the key diagram. The standard chemical symbols are used throughout this Code and are so well known that it is considered unnecessary to enumerate all of them.

2.1.2 When net efficiency is to be computed as outlined in Par. 6.2, it is necessary to determine certain values at points not indicated on Fig. 1. These items will carry subscripts higher than those shown on Fig. 1.

2.2 Symbols. A list of symbols for use in the computation is included at the end of this section. The chemical symbols are also used in some cases as subscripts.

2.2.1 With so many quantities and points of reference involved, it has been found impractical to restrict the Code to the use of single subscripts. Where both letter and numerical subscripts are used, the numerical one is given second; for example W_{se32} . This symbol means "W" for pounds, "s" for steam, "e" for elapsed time and " W_{se32} " then should be read "pounds of steam per hour at location 32 on Fig. 1" (Superheater outlet).

Symbols and Description

Symbol	Description	Unit
A	Air	.....
A'	Dry Air	.....
A.F.	As fired	.....
API_{gr}	Gravity of the fuel based on the API scale	deg API
A_s	Theoretical quantity of air required for complete combustion of the fuel	lb per lb of A.F. fuel
A_x	Excess air is the actual quantity of air used minus the theoretical air required divided by the theoretical air, and expressed as a percentage	per cent
a	Ash content of the fuel	per cent by weight
B	Heat credits added to the steam generator in the form of sensible heat	Btu
B_{Ae}	Sensible heat supplied by the entering air (rate)	Btu per hr
$B_{A'e}$	Sensible heat supplied by the dry entering air (rate)	Btu per hr
B_e	Heat credits added to the steam generator in the form of sensible heat (rate)	Btu per hr
B_{fe}	Sensible heat supplied with the fuel (rate)	Btu per hr
$B_{m Ae}$	Heat supplied from the moisture entering with the inlet air (rate)	Btu per hr
B_{xe}	Heat supplied by auxiliary drives (rate)	Btu per hr
B_{ze}	Heat supplied by the atomizing steam (rate)	Btu per hr
b	Burned	.....
C	Pounds of carbon per pound of "as fired" fuel - (laboratory analysis)	lb per lb of A.F. fuel
C_b	Pounds of carbon burned per pound of "as fired" fuel	lb per lb of A.F. fuel
CO	Per cent carbon monoxide per volume of dry flue gas. Determined by flue gas analysis	per cent
CO ₂	Per cent carbon dioxide per volume of dry flue gas. Determined by flue gas analysis	per cent
CO ₂ HC	The pounds of carbon dioxide formed from burning the hydrocarbon in the dry flue gas	lb per lb of dry gas
c	Specific heat	Btu per lb F
c_p	Specific heat at constant pressure	Btu per lb F
$c_{PA'}$	Mean specific heat of dry air at constant pressure	Btu per lb F
c_{pd}	Mean specific heat at constant pressure for the flue dust over the temperature from the reference to the flue gas temperature	Btu per lb F

Symbols and Description (Cont'd)

Symbol	Description	Unit
c_{pf}	Mean constant pressure specific heat of the inlet fuel determined for temperature difference between fuel inlet temperature and reference temperature	Btu per lb F
c_{pg}	Mean specific heat of the flue gas	Btu per lb F
c_{ps}	Specific heat of steam	Btu per lb F
D	Standard or guarantee	.....
d	Flue gas refuse (dust)	.....
d'	Dry flue gas refuse (dust)	.....
E	Energy	Btu
E_x	Energy consumed by auxiliaries	Btu
e	Elapsed time	hr
f	Fuel	.....
G	Flue gas	.....
G'	Dry flue gas	.....
g	Gross	.....
H	Pounds of hydrogen exclusive of that in moisture per pound of "as fired" fuel (laboratory analysis)	lb per lb of A.F. fuel
H_2	Hydrogen content of the flue gas (laboratory analysis)	cu ft per cu ft dry gas
HC	Per cent hydrocarbons per volume of dry flue gas (laboratory analysis)	per cent
$H_{d,p}$	High-heat value of total dry refuse (laboratory analysis)	Btu per lb of refuse
H_{fp}	High-heat value of the fuel at constant pressure	Btu per lb
H_{fv}	High-heat value of the fuel at constant volume	Btu per lb
H_f	High-heat value (chemical heat) of the fuel on the "as fired" basis (laboratory analysis)	Btu per lb
H_f'	High-heat value (chemical heat) of the fuel on a dry basis (laboratory analysis)	Btu per lb
H_r	High-heat value (chemical heat) of the pulverizer rejects (laboratory analysis)	Btu per lb
h	Enthalpy	Btu per lb
h_{Rw}	Reference enthalpy of entering moisture. It is the enthalpy of the liquid at the reference temperature	Btu per lb
h_{Rv}	Reference enthalpy of entering vapor. It is the enthalpy of the saturated vapor at the reference temperature	Btu per lb
h_s	Enthalpy of steam	Btu per lb
h_{sz}	Enthalpy of steam supplied to any auxiliary steam drive	Btu per lb

Symbols and Description (Cont'd)

Symbol	Description	Unit
h_v	Enthalpy of the vapor	Btu per lb
h_w	Enthalpy of the liquid	Btu per lb
i	Isentropic process	.....
K	Btu per cubic foot of dry flue gas (laboratory analysis)	Btu per cu ft of dry gas
(kwh)	Electrical energy	Kilowatt-hour
L	Heat loss from the steam generator which could have been added to the working fluid	Btu per lb of A.F. fuel
L_{CO}	Heat loss due to the formation of carbon monoxide	Btu per lb of A.F. fuel
L_d	Heat loss due to sensible heat in flue dust	Btu per lb of A.F. fuel
L_G	Heat loss due to heat in dry flue gas	Btu per lb of A.F. fuel
L_H	Heat loss due to moisture from burning hydrogen	Btu per lb of A.F. fuel
L_{mA}	Heat loss due to moisture in the combustion air	Btu per lb of A.F. fuel
L_{mf}	Heat loss due to moisture in the "as fired" fuel	Btu per lb of A.F. fuel
L_p	Heat loss due to radiation to ashpit, sensible heat in slag and, if applicable, latent heat of fusion of slag	Btu per lb of A.F. fuel
L_r	Heat loss due to heat in pulverizer rejects	Btu per lb of A.F. fuel
L_{UC}	Heat loss due to unburned carbon	Btu per lb of A.F. fuel
L_{UH}	Heat loss due to unburned hydrogen	Btu per lb of A.F. fuel
L_{UHC}	Heat loss due to unburned hydrocarbons	Btu per lb of A.F. fuel
L_u	Heat loss due to heat rejected to cooling water used within the envelope Fig. 1	Btu per lb of A.F. fuel
L_z	Heat loss due to heat in the atomizing steam	Btu per lb of A.F. fuel
L_β	Heat loss due to radiation and convection	Btu per lb of A.F. fuel
M	Molecular weight of any substance	lb per mole
M_{HC}	Molecular weight of hydrocarbons	lb per mole

ASME POWER TEST CODES

Symbols and Description (Cont'd)

Symbol	Description	Unit
m	Moisture content	per cent by weight
m_f	Moisture in fuel	lb of water per lb of A.F. fuel
m_p	Moisture in pit refuse	lb of water per lb of pit refuse
N	Pounds of nitrogen per pound of "as fired" fuel (laboratory analysis)	lb per lb of A.F. fuel
N_2	Per cent nitrogen per volume of dry flue gas. Determined by subtracting the sum of the measured quantities CO_2 , O_2 and CO from 100	per cent
n	Net	.....
O	Pounds of oxygen per pound of "as fired" fuel (laboratory analysis)	lb per lb of A.F. fuel
O_2	Per cent oxygen per volume of dry flue gas. Determined by flue gas analysis	per cent
P	Pressure	.....
P_A	Atmospheric pressure	psia
P_f	Pressure of gaseous fuel at the primary measuring element	psia
P_{mA}	The partial pressure or vapor pressure of the moisture in the air	psia
P_{mG}	The partial pressure or vapor pressure of the moisture in the flue gas	psia
P_s	Pressure of the steam measured at the point indicated by the appropriate numerical subscript (Fig. 1)	psia
P_w	Pressure of the water measured at the point indicated by the subscript number (Fig. 1)	psia
P	Ashpit refuse	lb
\boxed{P}	Ashpit	.....
P'	Dry pit refuse	lb
Q_{fe}	Quantity of gaseous fuel fired (rate) — based on 14.7 psia and 68 F. Note that the standard cu ft in the gas industry is based on 60 F and 14.73 psia	cu ft per hr
R	Reference	.....
R_u	Universal gas constant (1545)	ft-lb/lb mole, deg R
r	Pulverizer rejects	lb
S	Pounds of sulfur per pound of "as fired" fuel (laboratory analysis)	lb per lb of A.F. fuel

Symbols and Description (Cont'd)

Symbol	Description	Unit
SO_2	Per cent sulfur dioxide per volume of dry flue gas (laboratory analysis)	per cent
s	Steam	.....
T	Temperature Rankine	R
t	Temperature Fahrenheit	F
t_{RA}	Reference air temperature is the base temperature to which sensible heat losses and credits are compared for efficiency computations	F
t_A	Temperature of air	F
t_f	Temperature of fuel	F
t_G	Temperature of flue gas	F
t_s	Temperature of steam	F
t_u	Temperature of the water	F
U	Unburned	.....
V	Volume of any substance - substance indicated by subscript	cu ft
v	Vapor	.....
W	Weight	lb
W_A	Pounds of moist air supplied per pound of "as fired" fuel	lb per lb of A.F. fuel
W_A'	Pounds of dry air supplied per pound of "as fired" fuel	lb per lb of A.F. fuel
W_{Ae}	Pounds of air supplied (rate)	lb per hr
$W_{A'e}$	Pounds of dry air supplied (rate)	lb per hr
W_G	The pounds of dry gas leaving unit per pound of "as fired" fuel	lb per lb of A.F. fuel
$W_{d'p}$	Pounds of dry refuse per pound of "as fired" fuel	lb per lb of A.F. fuel
$W_{d'p'e}$	Pounds of dry refuse collected (rate)	lb per hr
W_{fe}	Pounds of fuel fired (rate) either solid or liquid	lb per hr
$W_{G'N_2}$	Pounds of nitrogen in dry gas per pound of "as fired" fuel	lb per lb
W_{mA}	Pounds of moisture per pound of dry air	lb per lb of dry air
W_{se}	Pounds of steam per hour flowing at any location identified by appropriate numerical subscript	lb per hr
W_{sxe}	Pounds of steam supplied (rate) to all the steam driven auxiliaries	lb per hr
W_{ue}	Pounds of water (rate)	lb per hr
W_z	Pounds of atomizing steam per pound of "as fired" fuel	lb per lb of A.F. fuel

Symbols and Description (Cont'd)

Symbol	Description	Unit
w	Water	.....
X	Excess	.....
x	Auxiliary	.....
z	Atomizing steam	.....
B	Radiation and convection	.....
γ	Gas specific weight at 68 F and 14.7 psia	lb per cu ft of gas
δ	Corrected	.....
η	Efficiency	per cent
η_g	Gross efficiency	per cent
η_n	Net efficiency	per cent
η_x	Efficiency of auxiliary drives	per cent
θ	Theoretical	.....
ψ	The number of pound moles of any substance — substance indicated by subscript	.....
'(prime)	Dry	.....
Δ	Change	.....

2.3 Test and Run. Throughout this Code the word "test" is applied only to the entire investigation, and the word "run" to a subdivision. A run consists of a complete set of observations made for a period of time with one or more of the independent variables maintained virtually constant.

SECTION 3, GUIDING PRINCIPLES

3.01 Items on Which Agreement Shall be Reached. In order to achieve the objectives of the test the interested parties must reach agreement on the following pertinent items:

3.01.01 Gross efficiency determination – Defined in Par. 1.06.

3.01.01.1 General method – Heat loss or input-output.

3.01.01.2 Heat credits to be measured.

3.01.01.3 Heat credits to be assigned where not measured.

3.01.01.4 Heat losses to be measured.

3.01.01.5 Heat losses to be assigned where not measured.

3.01.01.6 Permissible deviation in efficiency between duplicate runs.

3.01.02 Capacity or Output – Defined in Par. 1.05.

3.01.03 Other related operating characteristics – See Section 8.

3.01.04 Allocation of responsibility for all performance and operating conditions which affect the test.

3.01.05 Selection of test personnel to conduct the test.

3.01.06 Establishment of acceptable operational conditions, number of load points, duration of runs, basis of rejection of runs and procedures to be followed during the test.

3.01.07 Cleanliness of unit initially and how this is to be maintained during the test. See Par. 3.04.2.

3.01.08 Actual air leakage to be allowed, if any, initially or during the test.

3.01.09 The source of thermodynamic properties to be used. Sources such as "Thermodynamic Properties of Steam" by Keenan and Keyes, and ASME Supplement thereto, and "Vapor Charts" by Ellenwood and Mackey are acceptable.

3.01.10 The fuel to be fired, the method of obtaining fuel samples and the laboratory to make the analysis.

3.01.11 Observations and readings to be taken to comply with the object or objectives of the test.

3.01.12 Instruments to be used, calibration of instruments, methods of measurement and equipment to be used in testing the unit. The Power Test Code Supplements on Instruments and Apparatus should be used, when applicable.

3.01.13 Tolerances and limits of error in measurement and sampling.

3.01.14 Distribution of fuel refuse quantities between various collection points and methods of sampling.

3.01.15 Corrections to be made for deviations from specified operating conditions.

3.02 Selection of Personnel. To insure obtaining reliable results, all personnel participating in the test shall be fully qualified to perform their particular function.

3.03 Tolerances and Limits of Error. This Code does not include consideration of over-all tolerances or margins on performance guarantees. The test results shall be reported as computed from test observations, with proper corrections for calibrations.

3.03.1 Allowances for errors of measurement and sampling are permissible provided they are agreed upon in advance by the parties to the test and clearly stated in the test report. The limits of probable error on calculated steam generator efficiency, shall be taken as the square root of the sum of the squares of the individual effects on efficiency.

3.03.2 Whenever allowances for probable errors of measurement and sampling are to be taken into consideration, the reported test results shall be qualified by the statement that the error in the results may be considered not to exceed a given plus or minus percentage, this value having been determined in accordance with the foregoing method for computing limits of probable error.

3.03.3 The following table is included as a guide to show the effect on efficiency of measurement errors exclusive of sampling errors. The measurement error range in the table is not intended to be authoritative but conforms approximately with experience. The values in the table are not intended to be used in any calculation of test results.

**PROBABLE MEASUREMENT ERRORS
AND RESULTING ERRORS IN EFFICIENCY CALCULATIONS**

3.03.4 1 - Input-Output Method

Measurement	Measurement error, per cent	Error in calculated Steam Generator Efficiency, per cent
(1) Weigh tanks (calibrated scales)	± 0.10	± 0.10
(2) Volumetric tanks (calibrated)	± 0.25	± 0.25
(3) Calibrated flow nozzle or orifice including manometer	± 0.35	± 0.35
(4) Calibrated flow nozzle or orifice including recorder	± 0.55	± 0.55
(5) Coal scales - Batch or dump (calibrated)	± 0.25	± 0.25
(6) Uncalibrated flow nozzle or orifice including manometer	± 1.25	± 1.25
(7) Uncalibrated flow nozzle or orifice including recorder	± 1.60	± 1.60
(8) Fuel heating value (coal) (gas and oil)	± 0.50 ± 0.35	± 0.50 ± 0.35
(9) Reheat flow (based on heat balance calculations)	± 0.60	± 0.10
(10) Superheater outlet temperature (calibrated measuring device)	± 0.25	± 0.15
(11) Superheater outlet pressure (calibrated measuring device)	± 1.00	± 0.00
(12) Reheater inlet and outlet temperature (calibrated measuring device)	± 0.25	± 0.10
(13) Reheater inlet and outlet pressure (calibrated measuring device)	± 0.50	± 0.00
(14) Feedwater temperature (calibrated measuring device)	± 0.25	± 0.10

2.03.5 II - Heat Loss Method

3.04 Acceptance Test. An acceptance test shall be undertaken only when the parties to the test certify that the unit is operating to their satisfaction and is, therefore, ready for test. Especially in the case of fuel burning equipment, adjustments and changes are sometimes necessary to obtain optimum performance. The acceptance test should be started as soon as the unit is in satisfactory condition for test, provided the load and other governing factors are suitable.

3.04.1 Parties to the test may designate a person to direct the test and to serve as arbiter in the event of disputes as to the accuracy of observations, conditions or methods of operation, see Par. 8.04.1.

3.04.2 All heat transfer surfaces, both internal and external, should be commercially clean (normal operating cleanliness) before starting the test, refer to Par. 3.01.7. During the test, only the amount of cleaning shall be permitted as is necessary to maintain normal operating cleanliness.

3.04.3 After a preliminary run has been made, it may be declared an acceptance run if agreed to and provided that all the requirements of a regular run have been met.

3.04.4 At least two runs shall be made approximating the load required for acceptance. If the

results exceed the previously agreed upon deviation in efficiency between runs, a third run will be required. The test efficiency at the required load will be the average of the two runs which fall within the permissible deviation in efficiency.

3.05 Preparation for All Tests.

3.05.1 The entire steam generating unit shall be checked for leakage. Air heater internal leakage shall also be checked. Excessive leakage shall be corrected.

3.05.2 Before the test is started, it shall be determined whether the fuel to be fired is substantially as intended.

3.05.3 Any departures from standard or previously specified conditions in physical state of equipment, cleanliness of heating surfaces, fuel characteristics, or constancy of load, shall be described clearly in the report of the test.

3.06 A Preliminary Run shall be made for the purpose of:

3.06.1 Checking the operation of all instruments.

3.06.2 Training the observers and other test personnel.

3.06.3 Making minor adjustments, the needs for which were not evident during the preparation for the test, and establishing proper combustion con-

ditions for the particular fuel and rate of burning to be employed.

3.07 Starting and Stopping. Combustion conditions, rate of feeding fuel (also quantity of fuel on grate if stoker fired), rate of feeding water, water level in drum (if of drum type), excess air and all controllable temperatures and pressures shall be, as nearly as possible, the same at the end of the run as at the beginning. These, and any other conditions in which variations might affect the results of the test, shall be essentially reached and held as constant as possible. There must be reasonable assurance that the temperature of the refractories of the setting and all other parts of the equipment have reached equilibrium before the run is started. The time required to attain stabilization or equilibrium with respect to temperatures will vary widely with the design of the unit and character of materials in the setting. This period of stabilization can vary from a minimum of one hour to more than three hours.

3.07.1 In some instances it may be necessary to terminate a run prematurely because of inability to maintain one or more of the operating conditions at the desired value.

3.07.2 In order to attain the desired operating conditions when solid fuel is fired by stokers, it is essential that major cleaning and conditioning of the fuel bed shall be accomplished some length of time before the run starts and again the same length of time before the run is completed. Minor occasional normal cleaning of the fuel bed may be permitted during the run. Rate of burning or feeding fuel after the initial cleaning of fires shall be kept at that rate which is to prevail during the run. The fuel bed depth shall be the same at the beginning and end of the run. The ashpit shall be emptied either just after the initial and final cleaning and conditioning of the fuel bed or just before the start and end of the run so that the weight of refuse corresponds to the weight of coal burned.

3.07.3 In the case of runs to determine the maximum output at which the unit can be operated for a short period, the run should be started as soon as the maximum output is reached and continued until conditions necessitate terminating the run.

3.08 Duration of Runs.

3.08.1 When determining the efficiency of coal fired units, using pulverized coal or crushed coal

as in the case of cyclone firing, the runs should be preferably of not less than four hours duration. This duration is satisfactory even for tests conducted by the input-output method provided a unit system of pulverizers or crushers is used, and the fuel weighed as it is fed to the pulverizers or crushers. For those stations having a centralized fuel preparation plant, it may be impractical to weigh the fuel fed to any one unit, in which case the loss method should be used.

3.08.2 When determining the efficiency of a stoker fired steam-generating unit by input-output, the runs should be preferably of twenty-four hours duration. However, in the case of continuous ash discharge stokers, if conditions make it advisable, the length of a run may be reduced, but not to less than ten hours. The longer the duration of the runs the less will be the possibility of significant error due to estimating the difference in amount of unburned fuel on the grate at the beginning and end of the run. In many cases it is difficult to estimate the change in thickness of a large fuel bed closer than three inches. When the ratio of ash to unburned fuel is also indeterminate, the final estimate of effective change in bed thickness will frequently be in error by as much as four inches. The possible error due to estimating the effective change in the amount of unburned fuel on the grate at the beginning and end of each run should be considered in determining the duration of each run. Runs by heat loss method shall be of at least four hours duration.

3.08.3 When determining the efficiency of steam generating units fired with liquid or gaseous fuels, the runs should preferably be of not less than four hours duration.

3.08.4 For waste heat boilers, efficiency runs shall be for not less than four hours duration.

3.08.5 The duration of runs to determine the maximum short period output, when the efficiency is not to be determined, shall be by agreement of the parties to the test.

3.08.6 The actual duration of all runs from which the final test data are derived shall be clearly stated in the test report.

3.09 Performance Curves. It is desirable, but not mandatory, that runs be made at not less than four different outputs, so that curves may be drawn to relate the test points. Such curves, showing

pertinent test data, plotted against output, are very useful in appraising the performance of the unit, because the desired outputs are seldom exactly obtained during the test. Where there are enough test points to establish characteristic curves, the performance at any output may be read from the curves.

3.10 Frequency and Consistency of Readings.

Except for quantity measurements, the readings shall be taken at 15 minute intervals. If, however, there are fluctuations, the readings shall be taken at such frequency as may be necessary to determine the average.

3.10.1 Where the amount of fuel or feedwater is determined from integrating instruments, a reading shall be taken every hour. If the quantities to be determined are weighed, the frequency of weighing is usually determined by the capacity of the scales, but the intervals shall be such that a total can be obtained for each hour of the test. The time shall be recorded when each hopper of coal or each tank of feedwater is dumped. When indicating flowmeters or manometers are used with venturi tubes, flow nozzles or orifice plates for subsequently determining quantity measurements, the flow indicating element shall be read at five minute intervals or more frequently when deemed necessary.

3.10.2 It is suggested that, in so far as feasible, pertinent data of the run be plotted continuously, as the run progresses, on coordinate paper of suitable scale arrangements to permit a complete review of the conduct of the run at least hourly.

3.11 Rejection of Runs. Should serious inconsistencies in the observed data be detected during a run or during the computation of the results, the run shall be rejected completely, or in part if the affected part is at the beginning or at the end of the run. A run that has been rejected shall be repeated, if necessary to attain the objectives of the test.

3.12 Records and Test Reports. All observations, measurements and instrument readings necessary for the objective of the test shall be recorded as observed. Corrections and corrected values shall be entered separately in the test record.

3.13 Instruments and Methods of Measurement. The necessary instruments and procedures for

making measurements are prescribed herein and should be used in conjunction with the following ASME Power Test Codes Supplements on Instruments and Apparatus, and other publications for detailed specifications on apparatus and procedures involved in the testing of steam-generating units. In all cases, care shall be exercised to refer to the latest revision of the document concerned.

3.13.1 ASME Power Test Codes:

General Instructions PTC 1
Definitions and Values PTC 2
Diesel and Burner Fuels PTC 3.1
Solid Fuels PTC 3.2
Gaseous Fuels PTC 3.3
Coal Pulverizers PTC 4.2
Air Heater PTC 4.3
Centrifugal, Mixed Flow and Axial Flow
Compressors and Exhausters PTC 10
Fans PTC 11
Dust Separating Apparatus PTC 21
Determining Dust Concentration in a Gas
Stream PTC 27

3.13.2 Supplements on Instruments and Apparatus PTC 19:

Part 1, General Considerations PTC 19.1
Part 2, Pressure Measurement PTC 19.2
Part 3, Temperature Measurement PTC 19.3
Part 5, Measurement of Quantity of Mater-
ials PTC 19.5
Part 6, Electrical Measurements in Power
Circuits PTC 19.6
Part 10, Flue and Exhaust Gas Analyses
PTC 19.10
Part 11, Determination of Quality of Steam
PTC 19.11
Part 12, Measurement of Time PTC 19.12
Part 13, Measurement of Rotary Speed
PTC 19.13
Part 16, Density Determinations PTC
19.16
Part 17, Determination of Viscosity of
Liquids PTC 19.17
Part 18, Humidity Determinations PTC
19.18
Part 21, Leakage Measurement PTC 19.21

3.13.3 ASME Research Publication:

Fluid Meters — Their Theory and Appli-
cation

3.13.4 American Gas Association:
Orifice Metering of Natural Gas - Gas
Measurement Committee Report No. 3,
April, 1955

3.13.5 ASTM Standard Methods:
Methods of Sampling Coals, D 492
Laboratory Sampling and Analysis of Coal
and Coke, D 271

3.13.6 National Bureau of Standards:
Heat of Combustion of Liquid Hydrocarbon
Fuels by Bomb Calorimeter, D 240
Test for Calorific Value of Gaseous Fuel
by the Water-Flow Calorimeter, D 900

Methods of Measuring Humidity and Test-
ing Hygrometers, Circular 512

APPENDIX V

POLYCYCLIC ORGANIC MATTER

APPENDIX V

POLYCYCLIC ORGANIC MATTER

ACENAPHTHYLENE
ACENAPHTHENE
ANTHRACENE
BENZO(a)ANTHRACENE
BENZO(b)FLUORANTHENE
BENZO(k)FLUORANTHENE
BENZO(a)FLUORENE
BENZO(b)FLUORENE
BENZO(ghi)PERYLENE
BENZO(a)PYRENE
BENZO(e)PYRENE
2-CHLORONAPHTHALENE
CHRYSENE
CORONENE
DIBENZO(a,c)ANTHRACENE
9,10 - DIMETHYLANTHRACENE
7,12 - DIMETHYLBENZO(a)ANTHRACENE
FLUORANTHENE
FLUORENE
INDENO(1,2,3 - cd)PYRENE
2 - METHYLANTHRACENE
3 - METHYLCHOLANTHRENE
1 - METHYLNAPHTHALENE
2 - METHYLNAPHTHALENE
1 - METHYLPHENANTHRENE
9 - METHYLPHENANTHRENE
NAPHTHALENE
PERYLENE
PHENANTHRENE
PICENE
PYRENE
TETRALIN
TRIPHENYLENE

